# Integrate Collaborative Project and Intellectual Asset Management for IC Design Industry

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## Abstract

*Owning to the rapid growth of consumer electronics market, there are urgent needs for better control over IC design projects, reuses of design knowledge (e.g., silicon intellectual property -- SIP), and design collaboration in a virtual design platform. In order to provide IC industry a well-integrated design environment, this research proposes an information platform which combines the project management module, the design knowledge management module and the collaborative working environment for the IC industry. With the help of the project management module, the R&D team leaders can better control its partners' and its own schedules to shorten the time to market. Moreover, the design knowledge (SIP) management module provides the IC companies and their partners a knowledge exchange environment to enrich the design chain productivity and efficiency. Finally, the integration of collaborative working environment is the propeller to enable collaborative design. With the collaborative project and knowledge management platform, IC companies gain competitive advantages when working as a virtual design team.*

**Keywords:** IC design, Project Management, Knowledge Management, SIP, Collaborative Product Design.

## 1. Introduction

Development of integrated circuits (IC) with multi-million gates is a very complicated task. It usually takes a working team consisting of research staffs from several departments and companies to realize the design concept and to deliver the satisfactory result. IC design processes require huge knowledge and experience as the solid base to generate the design concept and help specify the design details. Most of the knowledge comes from technical documents which describe the related silicon intellectual properties (SIPs), patents and enterprise's accumulated design experiences [1] [9] [11] [12]. However, the generation rate of knowledge is at an inestimable speed that it is almost impossible to read and analyze these documents via human efforts [3] [13]. Consequently, applying an automatic mechanism to help engineers read and analyze and even generate reports is needed [4] [10]. Moreover, with enhancement of project management, all team-members will know exactly the project status to accurately control the schedules and thus ensure the project and its related tasks can be accomplished on time. To meet the requirements, a web-based collaborative project management tool must be provided so that every participant can review the project intermediately [5] [6]. Furthermore, redesign and engineering changes are common issues nowadays since we are facing the customer-oriented market [2] [7]. To quickly and dynamically adjust the design concept and the engineering processes to meet the market demand and design requirement, a collaborative working environment is urgently needed [8] [14]. The collaborative working environment offers virtual conference room that engineers and managers from different locations can gather together via the access of Internet. In the virtual conference room, they can synchronously review the same CAD files, document files and other formats of files on their own desktops to make design decisions together with other team members on-line. Current researches are devoted to help industries solve problems via the above function modules. However, theses research only focus on one or at most two aspects depicted above. This research proposes an information system that jointly combines all three function modules and takes IC design lifecycle processes into consideration to provide industry-

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specific total solutions to enhance the competitive edges. In the following sections, the current practice is depicted to point out the on-going challenges. Afterward, the proposed system framework and function modules are presented. Finally, a case study of IC industry is discussed to show how the system helps the industry.

## 2. Current practice

According to field research and interviews with IC companies and their cooperative partners, it is concluded that the design partners are dissatisfied with current working environment. The major issues in collaborative IC design can be divided into three directions.

### 2.1. Project management

In the aspect of project management, most commercial solutions can help companies do the definition of work items and task scheduling. However, these solutions cannot provide efficient control mechanism and links for the managers and engineers to access real time project information. Thus, the team needs a better control and coordination of related resources to meet project goals.

### 2.2 Design knowledge and SIP management

When dealing with knowledge sharing, there may be many design teams in a company and every design team has its own design documents and SIPs. However, in the current practice, all these knowledge outputs are not well organized for efficient utilization. As a result, these intellectual properties cannot be efficiently shared among engineers for various projects. In searching outside information and knowledge, owing to deficient IP searching and organizing mechanism, the design team has very poor view on the development trend of technology development by competitors. Thus, the design team may easily fall into other companies' patent "traps" or get themselves into patent infringement disputes.

### 2.3 Collaborative environment

It is necessary to work cooperatively with partners outside the organization, so the design team must have a platform to discuss and confirm the design concept together. However, if the team members come from different locations, it is very inconvenient and costly for them to get together physically. Further, the design team delivers the design changes or engineering changes to related engineers from different departments via conventional ways (such as e-mail or fax) often raise the problems of information delays.

## 3. Integrate knowledge management and collaborative product design

To solve the problems depicted in the as-is model, this research develops an information platform that integrates the concepts of knowledge management and collaborative design project management to help IC industry better utilize its resource and knowledge. The proposed information platform simplifies the linkage and knowledge accessing approaches between the cooperative partners as shown in Figure 1. In the proposed model, users from different domains go to the same integrated platform. On this platform, they can co-design, search knowledge, share knowledge, trace the project status and even control and coordinate the project tasks. The major functional modules of the platform are discussed in details in the following subsections.

### 3.1 SIP document management

In SIP document management module, the system provides two ways of searching global IP repositories, i.e., the keyword searching and the full-text searching. Prior to the searching process, this research first trains the knowledge base in a given domain to gain the inference rules. Afterward, when IP engineers search for related patent documents, they can get effective search results. With the help of the kernel module, the performance of information collection will be improved. Moreover, this system also automatically categorizes the collected documents with consistency. With such assistance, the documents can be stored systematically based on their ontological profiles.

### 3.2 Design document management

Every design team brings forth some design outputs. However, in the current practice, these valuable results are not well stored, managed and reused. To solve this problem, this system provides document management function with version control capability. With this help, engineers and managers can always get the correct version they want without difficulties. With this centralized version control function, engineers from different divisions or groups can clearly understand other research and development trends and, thus, provide better asynchronous communication mechanism.

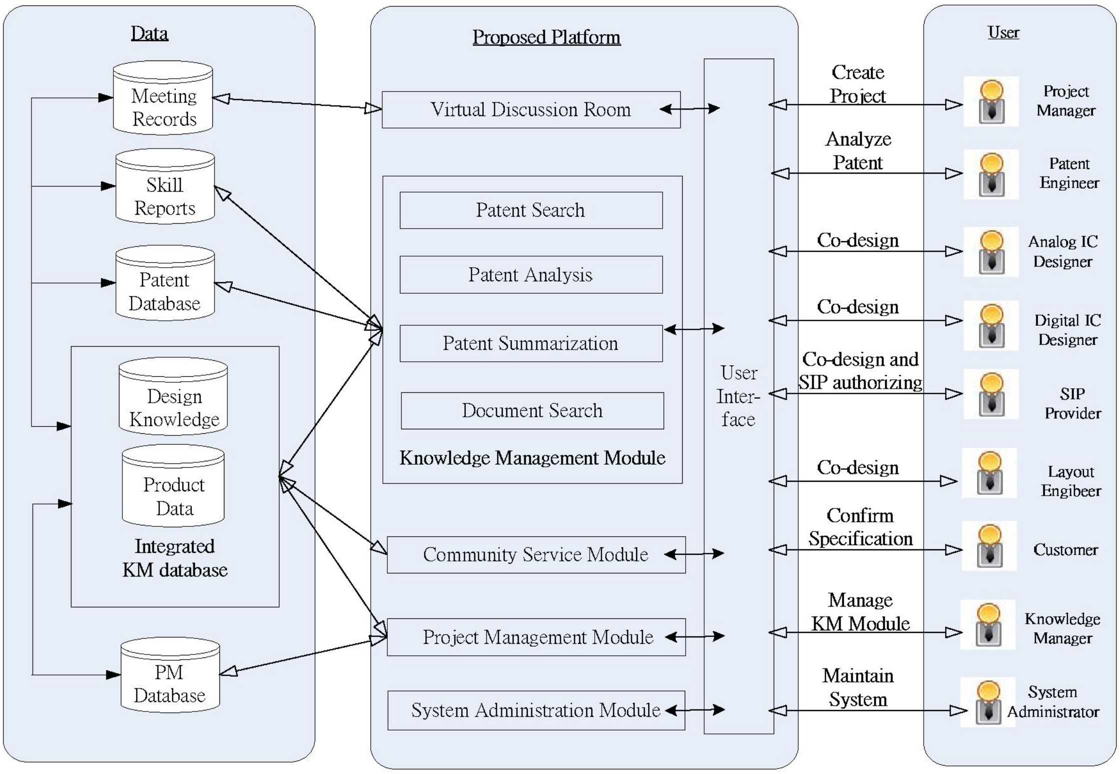


**Figure 1. The linkages between users, the collaborative platform and back-end databases**

### 3.3 Patent analysis and summarization

Related patent documents are analyzed using text mining techniques to understand current technology trend and competitors' status. However, it takes a lot of time for IP engineers to read the patent documents thoroughly to understand analyzed results. This system automatically analyzes the patent documents and generates summarization of the patent documents. With this function, engineers can get the key concepts of the patent quickly by reading their brief summaries and focus on the most related technology developments.

### 3.4 Project management

In the project management function module, project planning, project execution, project control and project evaluation are the four major sub-functions. The PM module uses the Petri-net representation approach to define the project phases in logical and hierarchical steps. Afterward, the PM module shows the project status and activity status to visualize the progress of the project. Furthermore, the system automatically notifies engineers in the proper time to execute their tasks and to ensure the project run smoothly. Finally, the system calculates the risk, cost and human resources of each project dynamically based on the fuzzy set logics. Therefore, the project manager can make accurate decisions during the project run.

### 3.5 On-line collaboration and coordination

To reach collaborative environment, both synchronous and asynchronous collaborations are supported. In the asynchronous collaboration, system sends e-mail messages to project participants regardless whether they attend the meeting or not to ensure information reaching all parties. In the synchronous collaboration, this system provides a platform for engineers and managers to co-work tasks in real-time. Via this function, they can discuss the design specification of certain design concept and do the modification and confirmation on-line. This function enables partners to do the drawing on CAD files or modification on documents on the synchronous screen. With this function module, the traveling time and cost are saved. Therefore, the time to market is shortened and capital utilization is increased.

## 4. Case study

The life cycle of IC design and fabrication includes a series of tasks, such as feasibility study, design and development, try run, pilot run and mass production. Each stage needs efforts from specific collaborative partners in a timely matter to fulfill the tasks and to ensure the project can be completed on time. Of all the stages, the design and development stage is the most critical one and its detailed processes are identified. This research uses SoC design processes as the case example to demonstrate the complex processes of IC design collaboration. SoC design mainly consists of

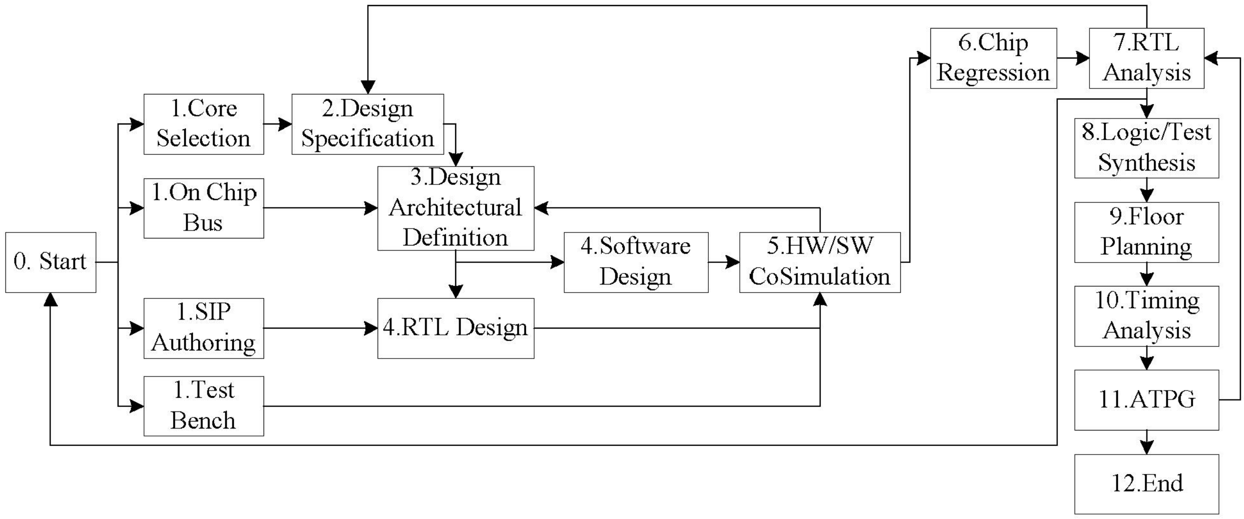


**Figure 2. The process flow of a System-on-a-Chip (SoC) design participated by collaborative partners**

steps such as design concept generation, SoC design, co-design, co-simulation, layout and post simulation and tape out. A detailed SOC design workflow is shown in Figure 2.

In design concept generation phase, patents and skill reports are analyzed carefully to determine the design domain. Afterward, project manager and its design team members start to generate the design concepts. After design concept is generated, the project manager defines the specifications of a SoC, and then defines the architecture of the system and the block function of a circuit according to demand specifications.

In the co-design phase, it requires multi participants' involvement. Usually, the digital IC designer, the analog IC designer and the SIP provider are three key co-designers with specific expertise. Digital IC designers firstly use hardware (HW) description language, e.g., Verilog, to describe demands and functions of circuit. After programming, digital IC designers run Verilog simulations to generate waveform to check if the waveform satisfies the expectations. If expectations are satisfied, digital IC designers synthesize the circuit into a transistor level circuit. Meanwhile, analog IC designers use Cadence Composer to do transistor level design and generate circuit schematic. Afterward, Software Process Improvement and Capability dEtermination (SPICE) simulations are run to check if demands are satisfied. In some critical technology domain, IC design companies need helps from SIP providers. More than the SIP authorization, SIP providers have to check if the demand specifications and parameters of designer's manufacturing processes are in accordance with IP providers' circuits.

After digital block and analog block ran their own simulations and receiving the authorization from SIP providers, the SoC design project goes to the phase of combining these three parts into a circuit. Moreover, co-simulation is run to check if expectations are met to determine whether the project can go to the layout phase.

After gathering the layout from digital block, analog block and SIP, an integrated layout is generated. Afterward, layout engineers do the verification of the integrated layout. There are usually three main steps in verification, i.e., the design rule check (DRC), the layout vs schematic (LVC) and layout parasitic extraction (LPE). DRC is applied to check whether the generated layout meets the design rules of manufacturing processes requested by the wafer Fab. For example, if the metal line of manufacturing processes for the 0.35-micron is less than 0.35 μ m, an error message occurs. The purpose of LVS is to check the input/output drawn in layout and the corresponding locations of components are in accordance with those in the previous designed circuit. LPE is the extraction of parasitic capacitance and resistance, and it considers the parasitic effects of the transistor and conducting wires. Taking LPE into consideration, a layout that approaches the real world is generated. After above verifications are accomplished, layout engineers do the post simulation. The purpose of post simulation is to run the simulation that considers parasitic effects. If the simulation results are acceptable, the project goes to the tape out phase. Tape out is the milestone of a design project. After reaching this point, the design project is accomplished and the manufacturing process starts.

How the integrated collaborative platform help the SOC design project execution is depicted as follows.

**I. Design concept generation**

In the design concept generation phase, engineers and managers have to read and analyze plenty of materials, including patents, skill reports and journal papers, to gain the design concept. The well organized knowledge management module of the system enables users to find useful historical research data and domain know-how quickly. Moreover, the patent search and analysis module helps find relative patents and summarize these patents into simplified format that engineers can quickly understand and utilize (Figure 3).

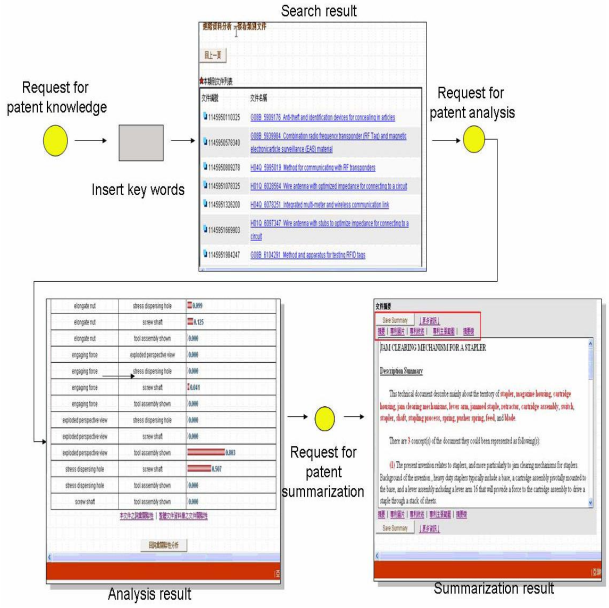


**Figure 3. The KM module offers patent search, analysis and summarization functions.**

**II. SoC design**

After determining the design domain and concept, project manager starts to define the design specifications, architecture and block functions. To reach satisfactory specifications and architecture, the design team and customer have to discuss mutually. Under such circumstance, the virtual conference room can offer a platform that these parties can jointly discuss regardless their different physical locations.

**III. Co-design**

In the co-design phase, the project is separated into three parts, and thus increases the difficulty to control the project status. The web-based project management helps to notify participants from different departments to catch up the project if the department is behind the schedule to better control the project status (Figure 4). Moreover, if design changes occur, this system automatically informs all related participants to ensure information synchrony.

**IV. Co-simulation**

It requires three parties' efforts to accomplish co-simulation. To assist them complete the simulation run in a more efficient way, the system provides a collaborative environment. In this collaborative environment, project participants from different departments can review the same CAD files, document files, and layout drawings on-line. Consequently, the time and money of co-simulation may be reduced owning that they don't have to meet together physically, and thus saves the time and money on traveling.

**V. Layout and Post Simulation**

This phase requires the ability of final verification and simulation. For some technical problems that require team discussion, the system provides a virtual collaboration and discussion forum for engineers to seek solutions together (Figure 5). Furthermore, the valuable experiences of project outcomes are stored and shared on the community service module.

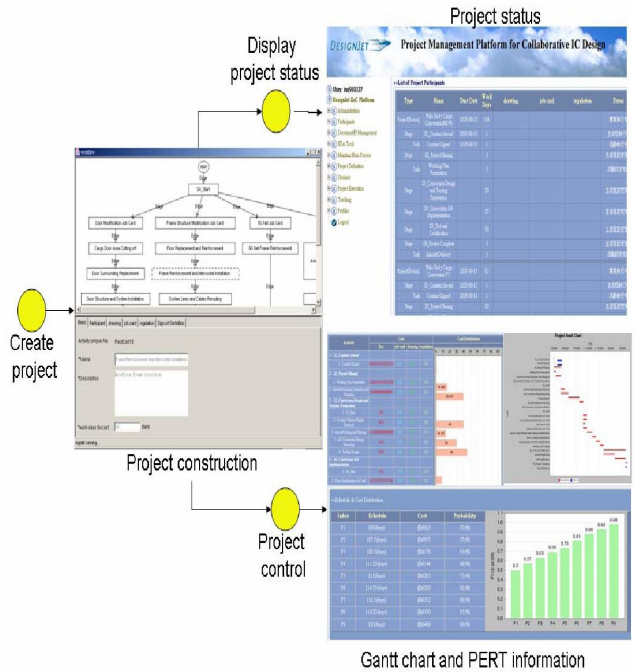


**Figure 4. The web-based PM module enables on-line project execution, reviews and control.**

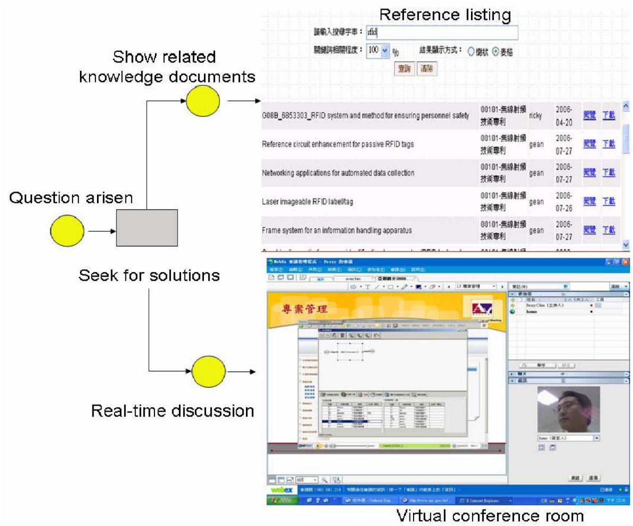


**Figure 5. The design community service module offers real-time discussion and knowledge sharing.**

## 6. Conclusion

Being different from current project management solutions for the IC industry, the collaborative project management services combine critical SIP, patent and knowledge management modules. With the integration of KM module, design team can capture the R&D trends and utilize the existing SIP knowledge. Furthermore, the collaborative environment is the focus of this research. Under the environment, participants from different locations work together synchronously and asynchronously. In the virtual conference room, they can co-work in a more efficient way, such as discussing the design concept, changing the design specification and confirming the design details. Meantime, the entire project status is under the control of the PM module. This proposed information platform consolidates the partnership of the cooperative design chain and increases the working efficiency via the integrated functional modules. The system helps the collaborative design with integrated PM and KM.

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